

TESTING OF A FIVE-CELL LIQUID-FEED DIRECT METHANOL FUEL CELL STACK FOR A 150-WATT SYSTEM.

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Introduction

Recent studies on direct methanol fuel cell (DMFC) technology has demonstrated that MEAs can be operated at low rates of airflow and moderate temperatures [1, 2]. This advancement is important in that it enables systems with DMFC stacks to operate with low-power ancillaries [3]. The testing of a stack made from such MEAs is the subject of this paper. Particular attention was focused on studying the water balance characteristics for long term system operation.

Experimental

A five-cell aqueous-feed direct methanol stack with an 80-cm² active electrode area has been developed and tested. The stack was designed for ultra low-pressure drop and efficient water removal characteristics in the cathode compartment. Parametric tests were performed to establish an operational envelope for recently developed MEAs. The fuel circulation loop was set up to ensure constant concentration of methanol during testing. This was accomplished by an automated feed system that incorporated a methanol concentration sensor.

Results and Discussion

The effects of methanol molarity on the average operating cell voltage at various loads for the five-cell stack is shown as figure 1. At 100 mA/cm² the average cell voltages for 0.4, 0.5, and 0.6M methanol are 0.27, 0.40, and 0.37V respectively. The lower cell voltage realized when operating at 0.4M methanol is attributed to a lack of sufficient methanol at the anode. The cell voltages observed at 0.6M are lower than that at 0.5M. This is attributed to the increased crossover observed at higher concentrations, placing an excessive demand on the oxygen available at the cathode [1]. In previous studies, it has been shown that the effect of methanol crossover on the cathode can be significant [1,4]. Thus, for values of air stoichiometry less than 2, 0.5M methanol is the optimal concentration for this DMFC.

The dependence of temperature on stack performance is shown in figure 2. An average operating cell voltage of 0.4V at 45-mA/cm² and 30 °C can be realized. The fuel cell being able to produce power at low temperatures enables ambient temperature applications and quick system start-up.

The continuous operation of the DMFC stack for over 70 hours is shown in Figure 3. In this experiment water exiting the cathode of the stack was collected and the neat methanol consumption was tabulated to determine a system water balance. Liquid water produced at the cathode was recovered. The drag coefficient was calculated to be 2.5, a number that is supported in the literature [5,6]. This experiment also showed that a water balance is possible for a stack operating at low airflow and 55 °C.

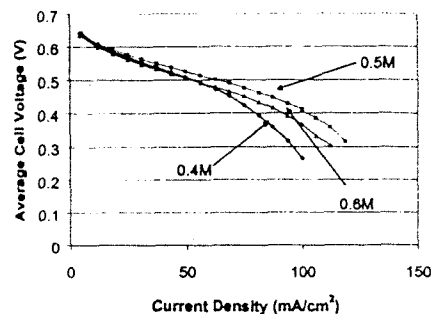


Figure 1. Average cell voltage as a function of current density and molarity. 55 - 60 °C, 1.75 L/min airflow.

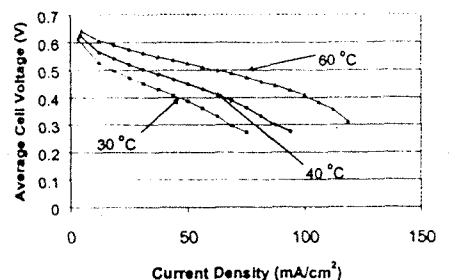


Figure 2. Average cell voltage as a function of current density and temperature. 0.5 M MeOH, 1.75 L/min airflow.

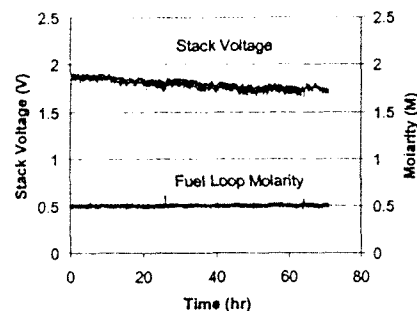


Figure 3. Extended testing at 100mA/cm² load, 0.5M MeOH, 200 cc/min MeOH circulation, 1.75 L/min airflow.

References

- 1-Valdez, T.I., Proceedings of Proton Conducting Membrane Fuel Cells II, ECS Proceeding Series, Pennington, NJ. 1998 pg. 330 -387
- 2-Zelenay, P., Proceedings of Proton Conducting Membrane Fuel Cells II, ECS Proceeding Series, Pennington, NJ. 1998 pg. 300 -315
- 3-Narayanan, S.R., Proceedings of Proton Conducting Membrane Fuel Cells II, ECS Proceeding Series, Pennington, NJ. 1998 pg. 316 -326
- 4-Narayanan, S.R., Proceedings of the 11th annual Battery Conference on Applications and Advances, Long Beach, CA., Jan 9-12, 1996. IEEE pg. 113 - 122
- 5-Valdez, T.I., Proceedings of the 11th annual Battery Conference on Applications and Advances, Long Beach, CA., Jan 9-12, 1997. IEEE pg. 239 - 244
- 6-Ren, X, J. Electrochemical Society, Vol. 144, No. 9, September 1997 pg. L267 -L270

[A3]



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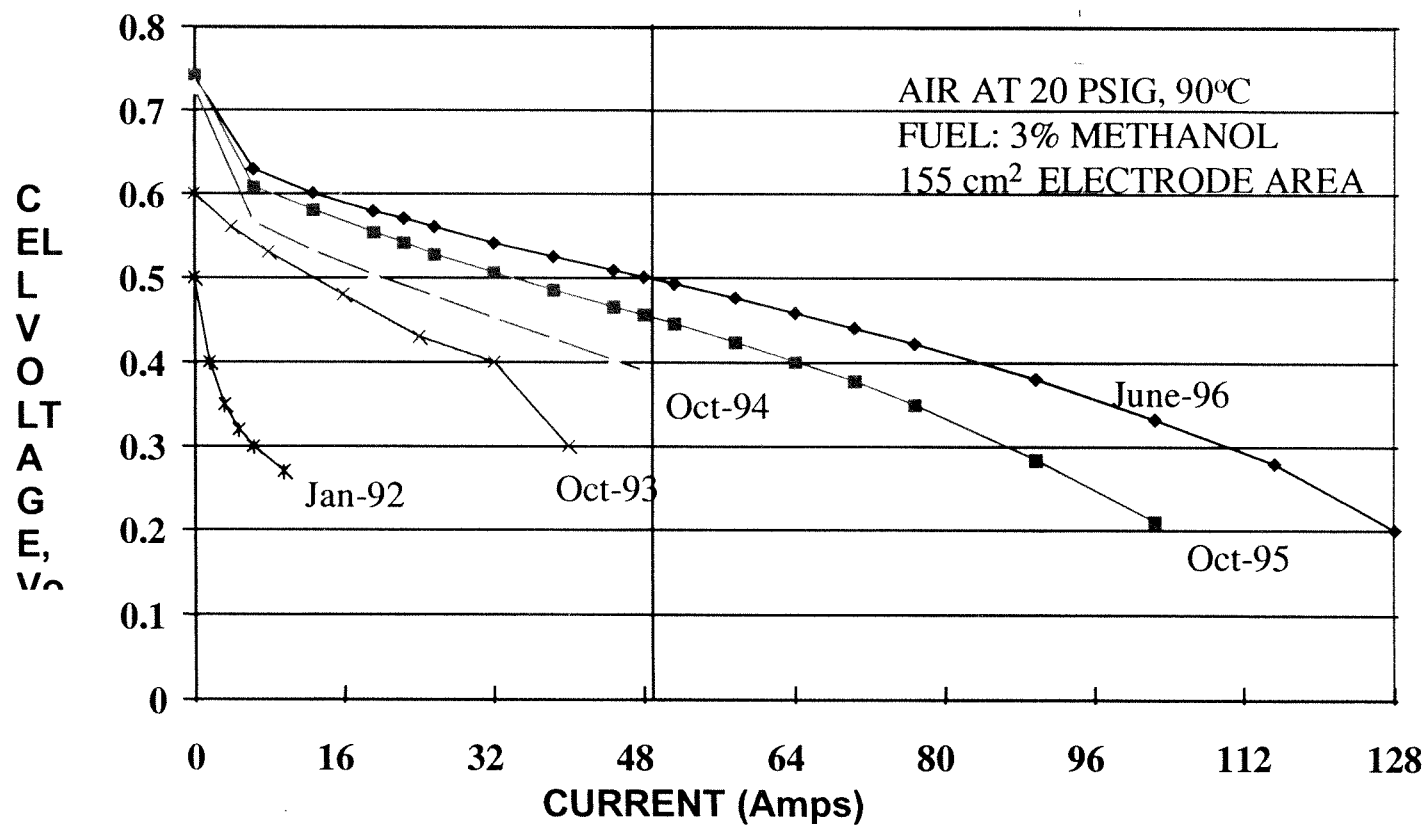
Direct Methanol Fuel Cell Research

- Development of a 150-watt auxiliary power unit.
 - Research is being ^{Funded} by DARPA.
- Reducing catalyst loading and development of novel catalyst.
 - Research being funded by the University of Minnesota for the ARO.
- Development of a 1kwatt system demonstrator
 - Research is being funded by AQMD and CARB.

Presentation Outline

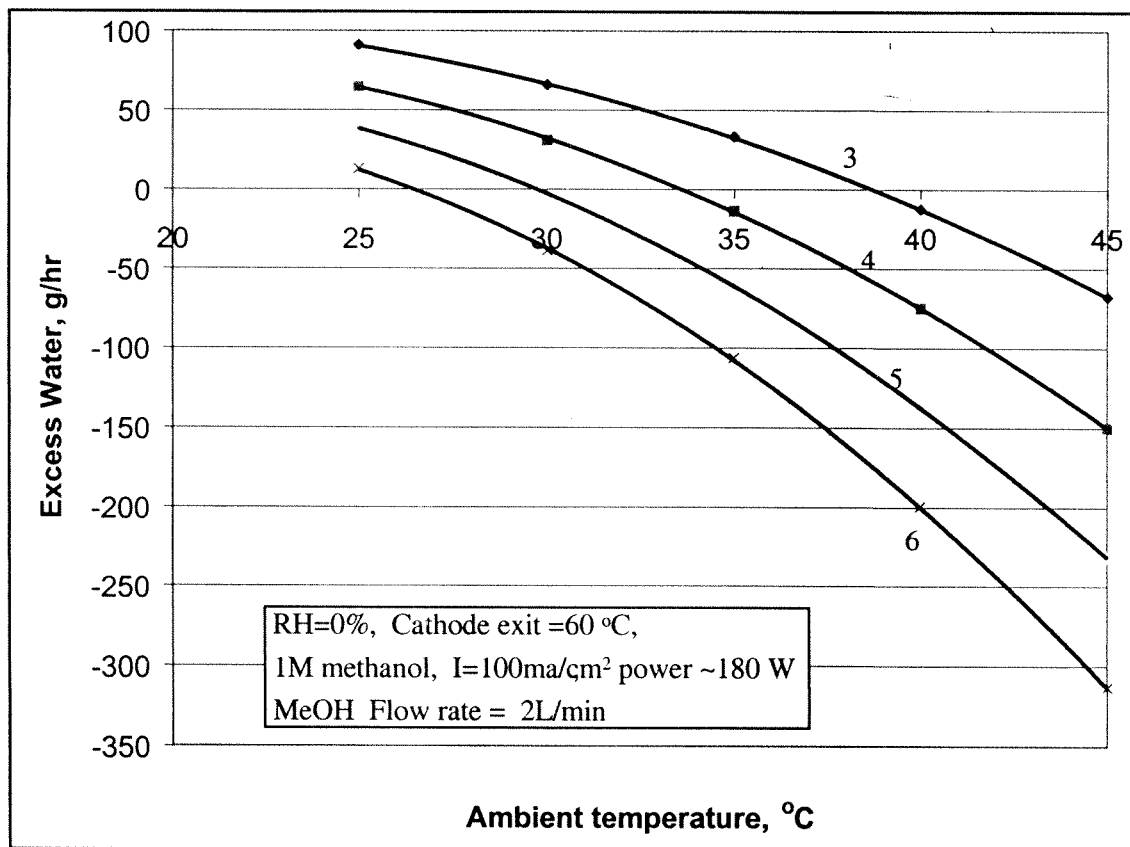
- DMFC Operating conditions
 - Airflow rate and operating temperature: Needed to maintain a water balance.
 - Methanol concentration: Optimized for maximum efficiency.
- DMFC Performance with improved cathode
 - Current- Voltage characterization vs. operating temperature.
 - Constant load characterization.
- Five Cell Stack Testing
 - Effects of temperature and molarity on stack performance.
 - Constant load characterization for long duration.

Progression of DMFC Research



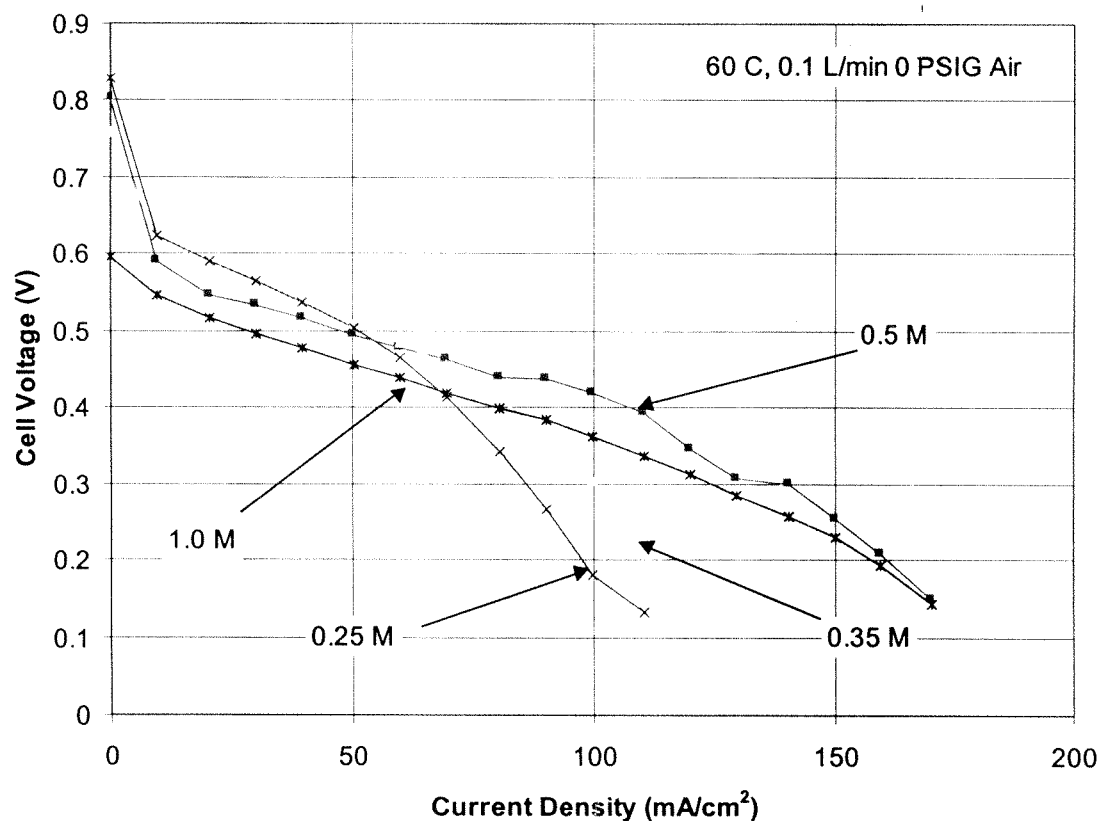
- After 1996, the focus for MEA development became system orientated

Excess water recovery and its dependence on stoichiometry



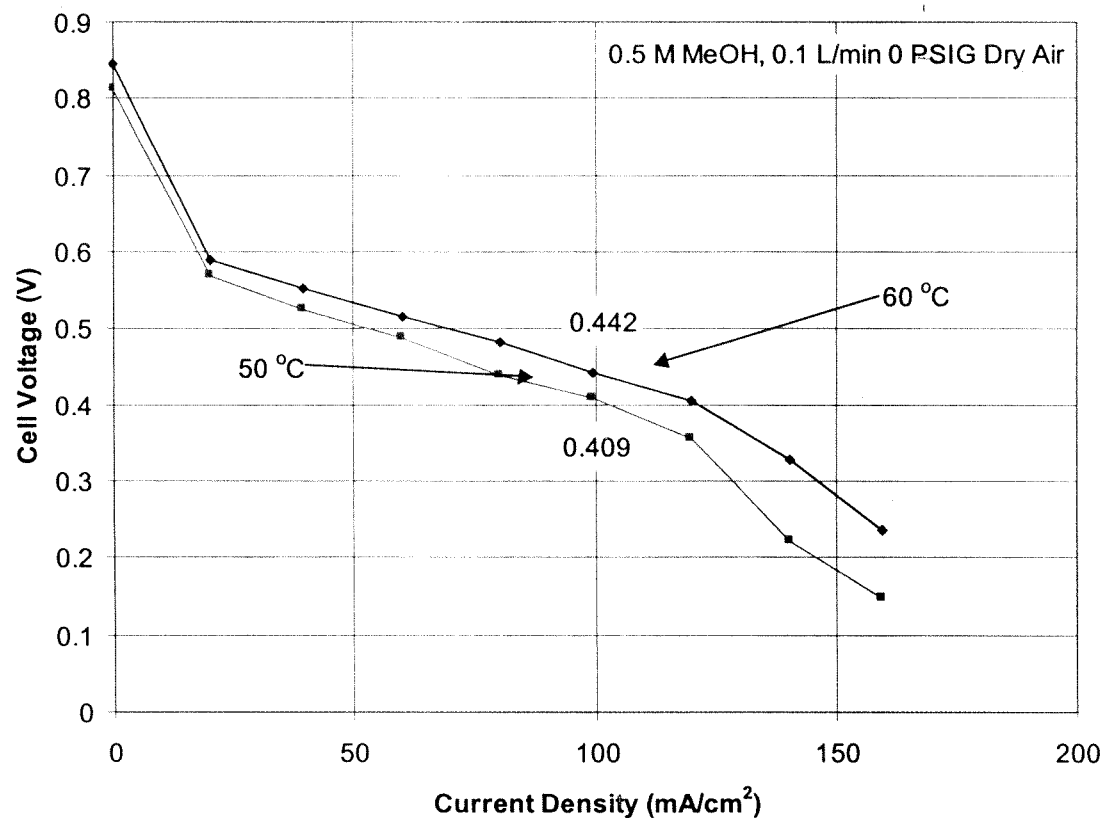
- The stoichiometry must be below 3 to maintain a system water balance above 40 °C, Narayanan *et al*

Methanol Concentration Effects on Single Cell Performance.



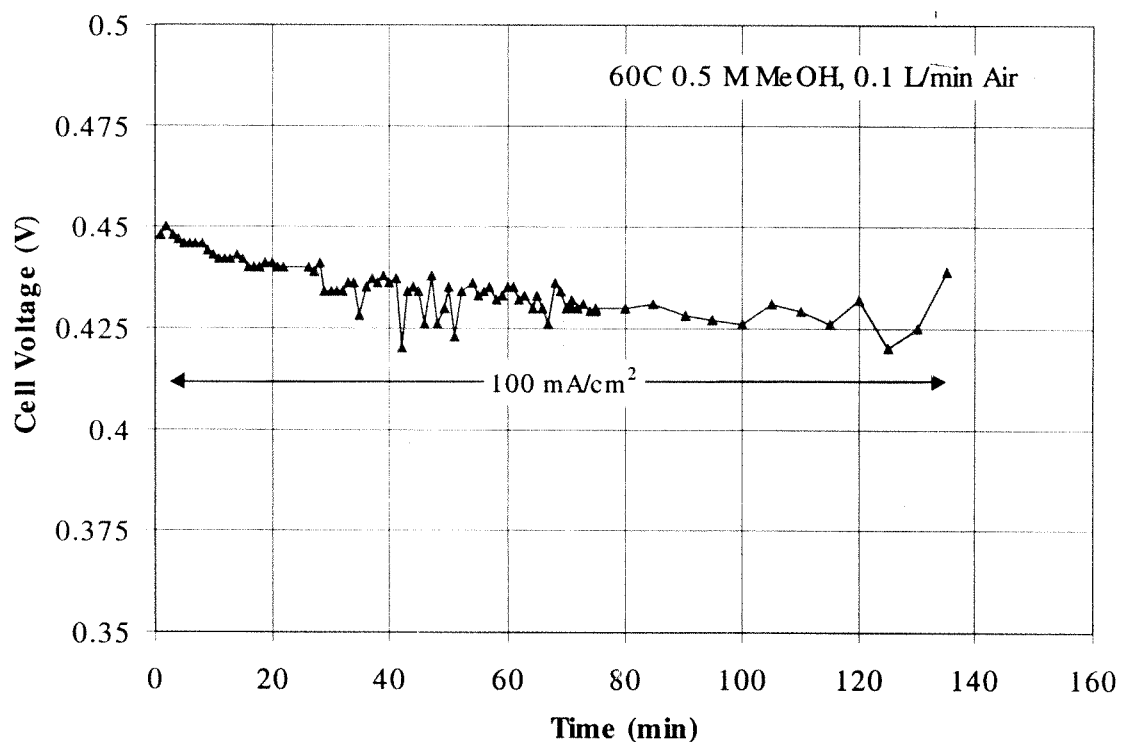
- 0.5M methanol is the better fuel concentration for cell operation at a 100 mA/cm²

Performance of cell with improved cathode



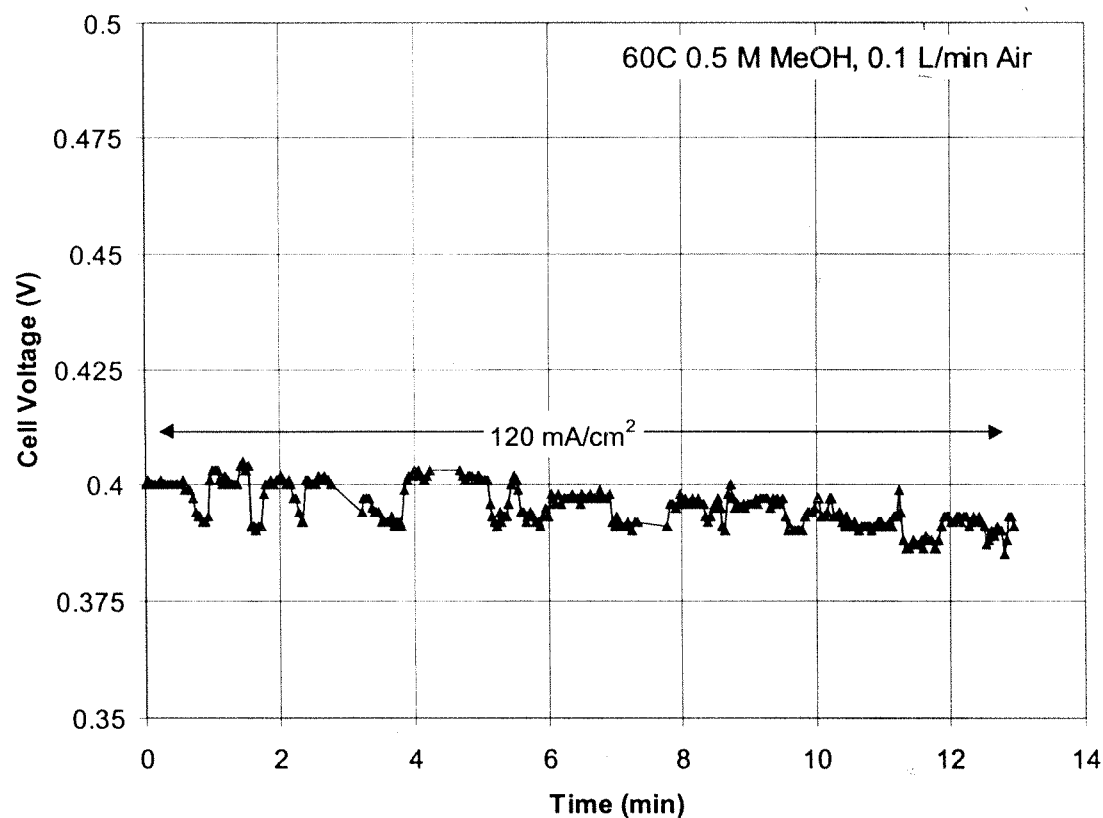
•Modified cathode results in improved performance, 20 mV improvement at 100 mA/cm².

Cell Stability at 100 mA/cm² (1.7 Stoic)



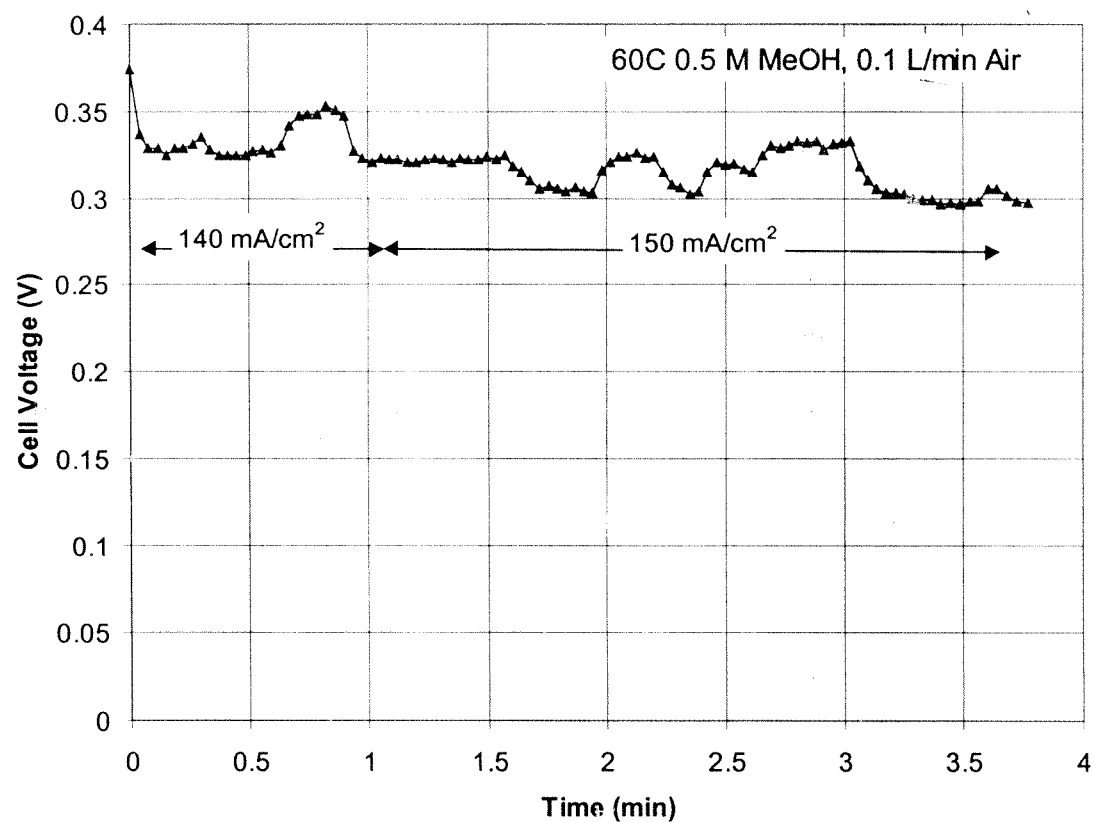
- 25cm² electrode area cell tested, low airflow stability adequate for stack operation.

Cell Stability, 120 mA/cm² (1.5 Stoic)



- Cell stable at higher loads, airflow 1.5 times stoichiometry (including crossover).

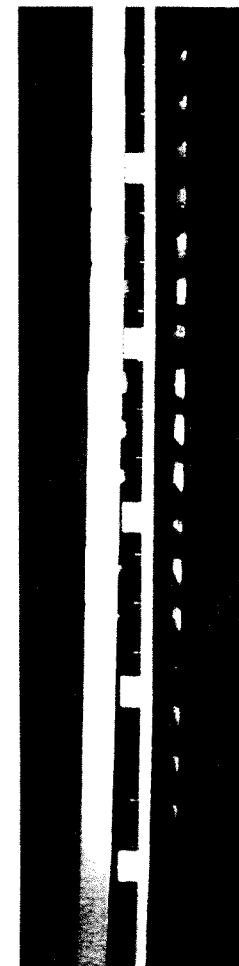
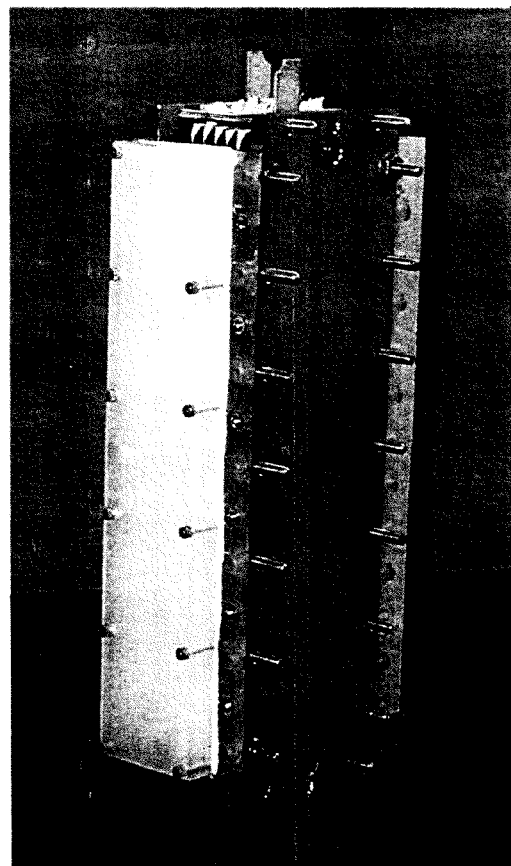
Performance at high current densities and low stoichiometry



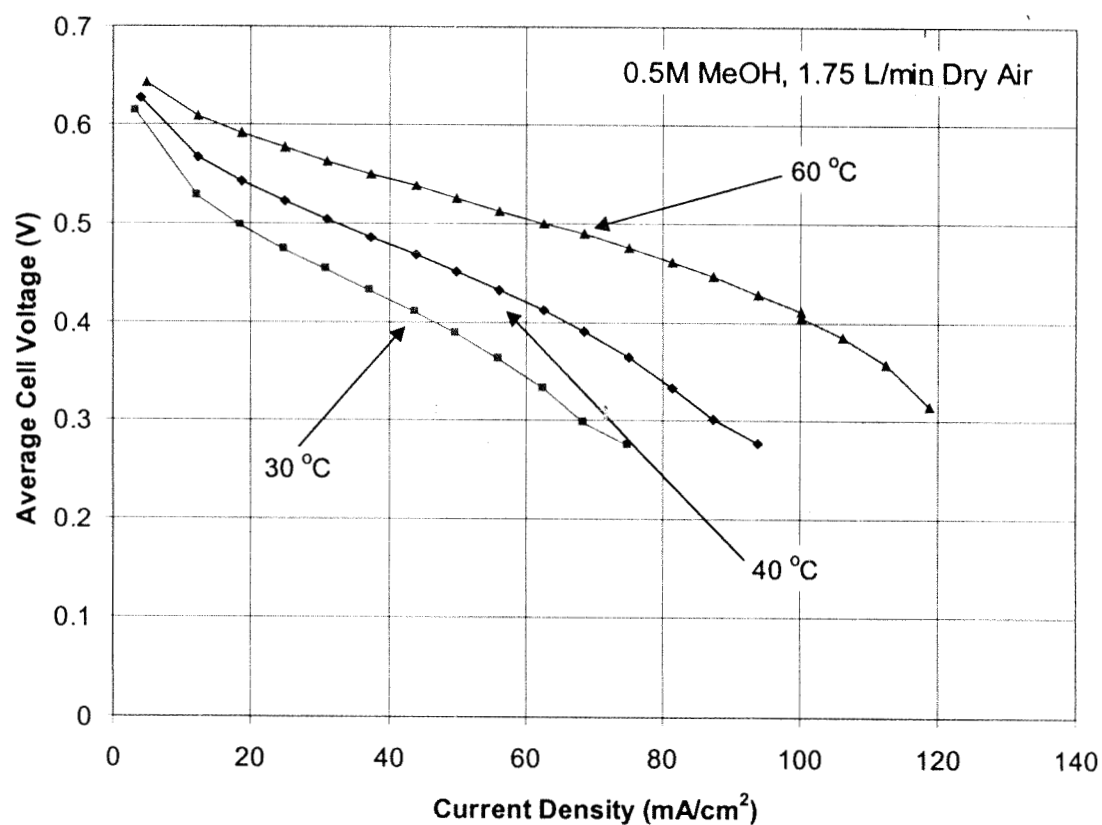
- Cell operation possible at current densities above 120 mA/cm² for short periods of times.

Five Cell Stack Testing

- MEA Scale-up
 - 80 cm² active area.
 - 12 mg/cm² cathode loading.
- Low Pressure Drop Design
 - Air diffuser had to be incorporated to insure uniform flow throughout the stack.
 - ΔP of 0.0525 inches of water with diffuser material.
- System Fuel Loop
 - Implementation of Gas-Liquid separator.
 - Concentration control with methanol sensor.



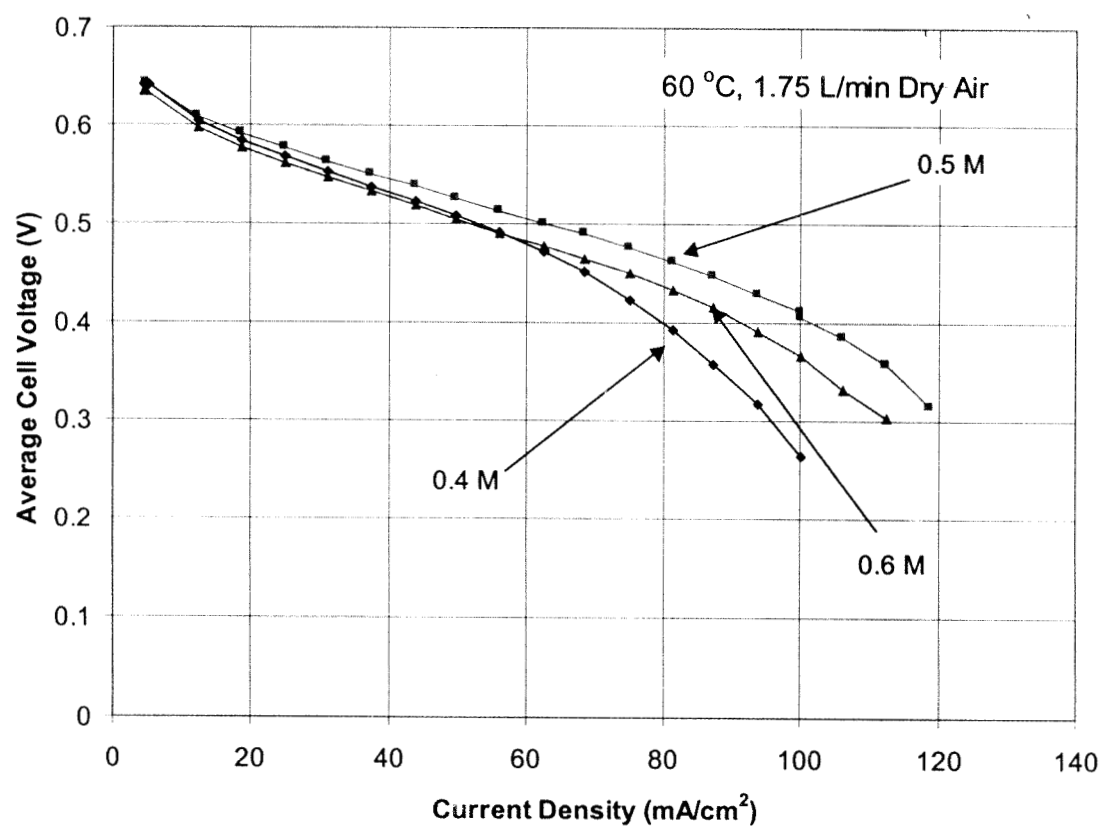
Stack Parametric Studies Effect of Temperature



- Significant stack power can be drawn at temperatures as low as 30 °C

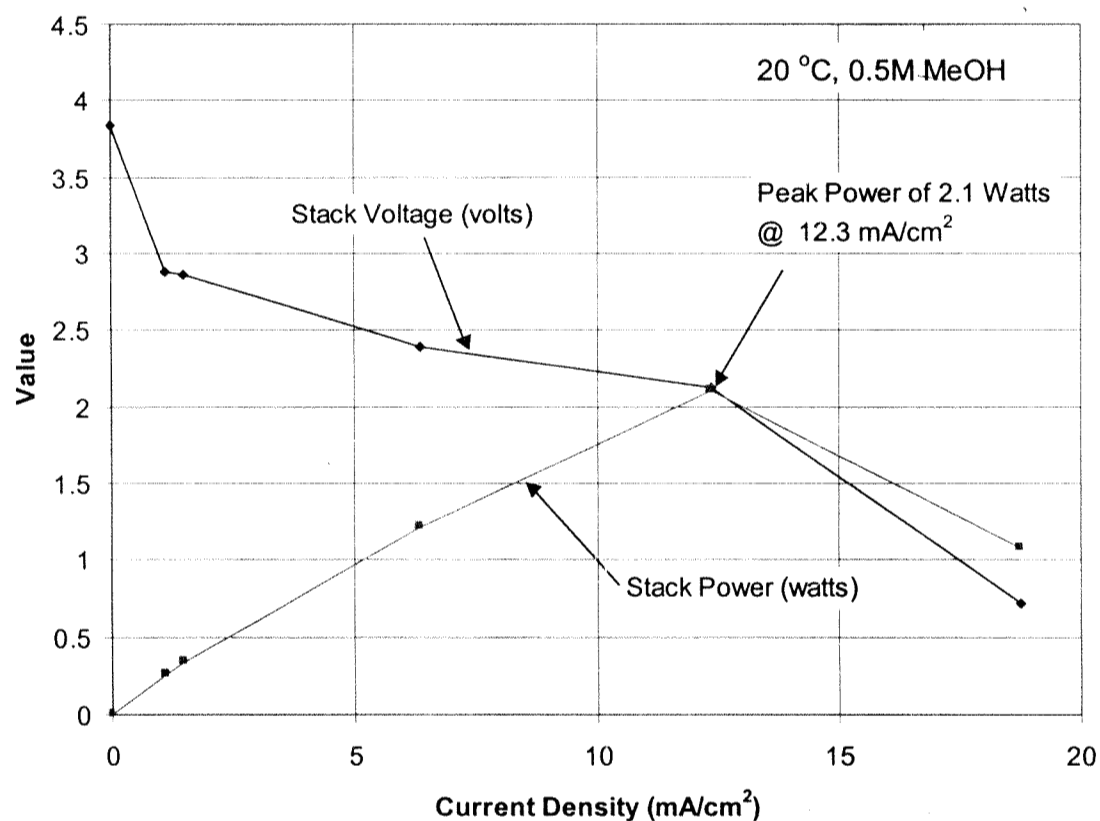
Stack Parametric Studies

Effect of Concentration



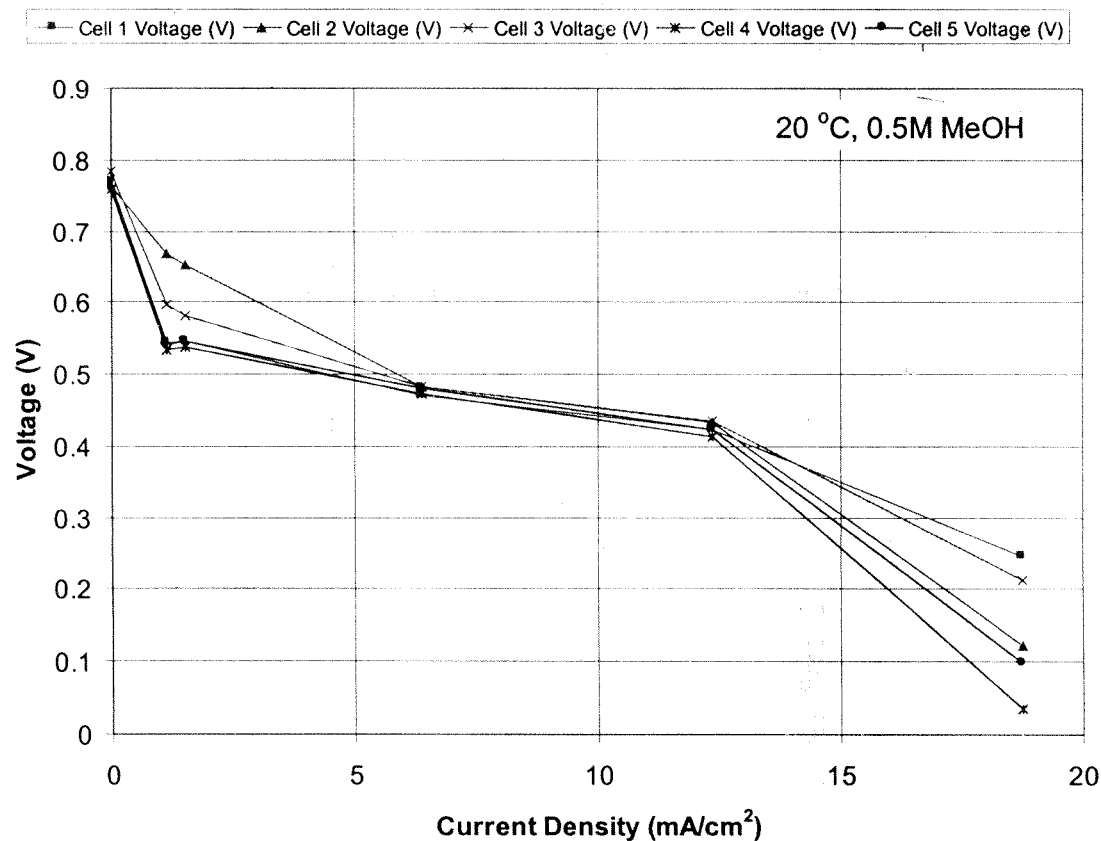
•0.5M methanol is the operating concentration of choice.

Startup Characteristics, No forced Airflow



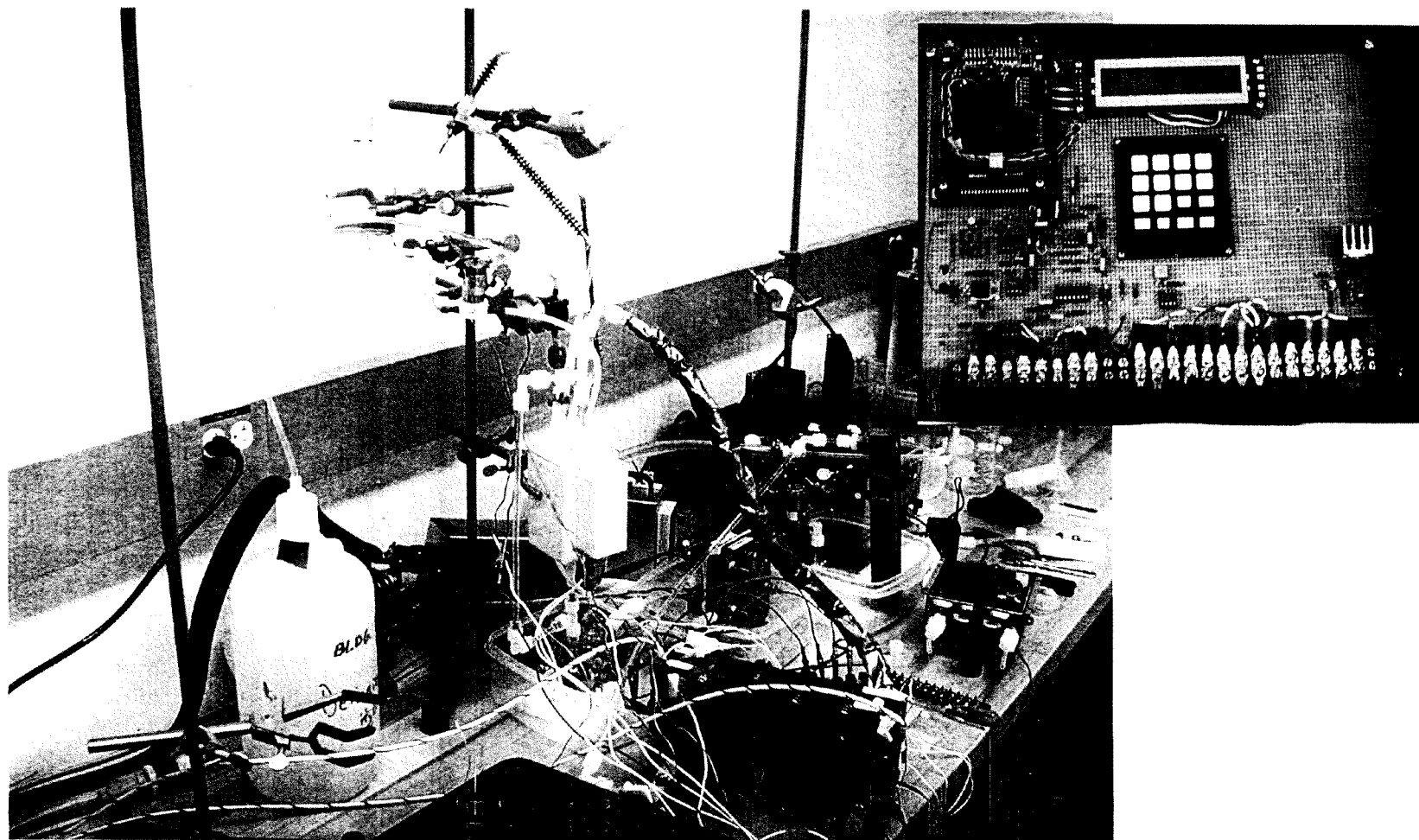
- Open structure of the stack allows for minimal operation with no forced airflow.

Start-up Characteristics, No Forced Airflow

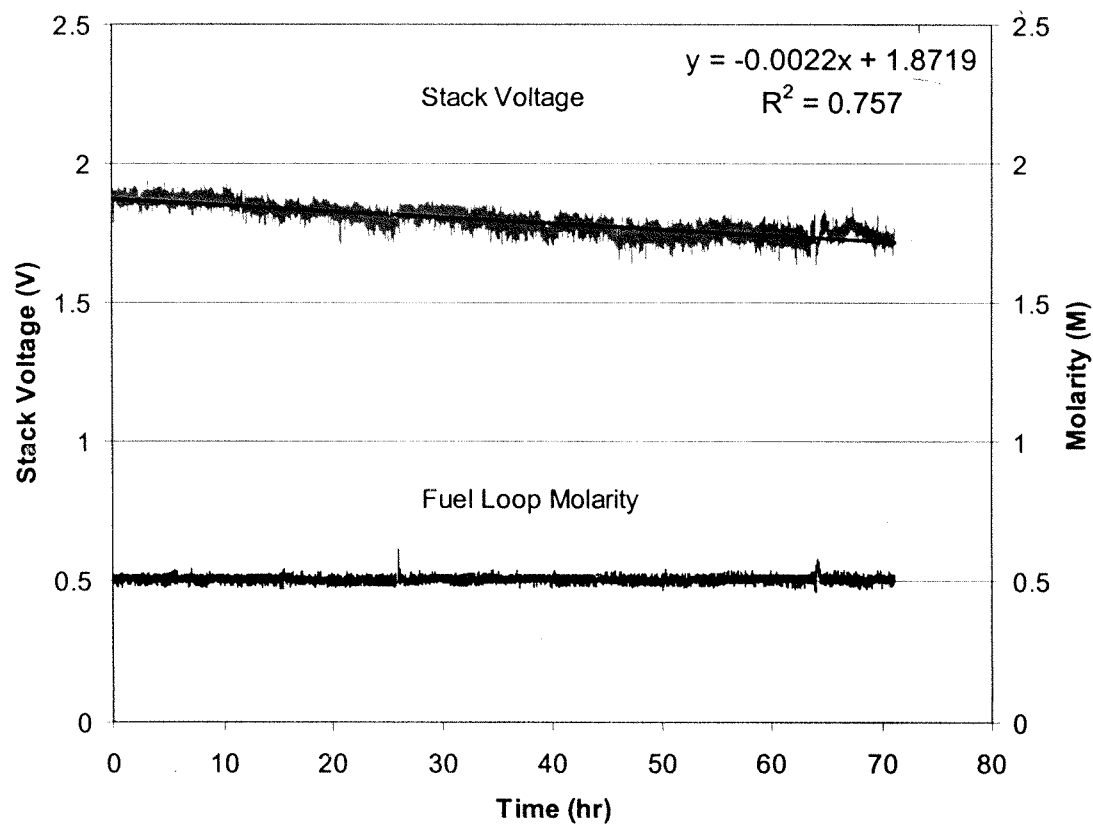


•Cell to cell variation minimal.

Long Term Testing



Long Term Testing



- Decline of stack voltage on the order of 2 mV per hour, completely recoverable.

Acknowledgements

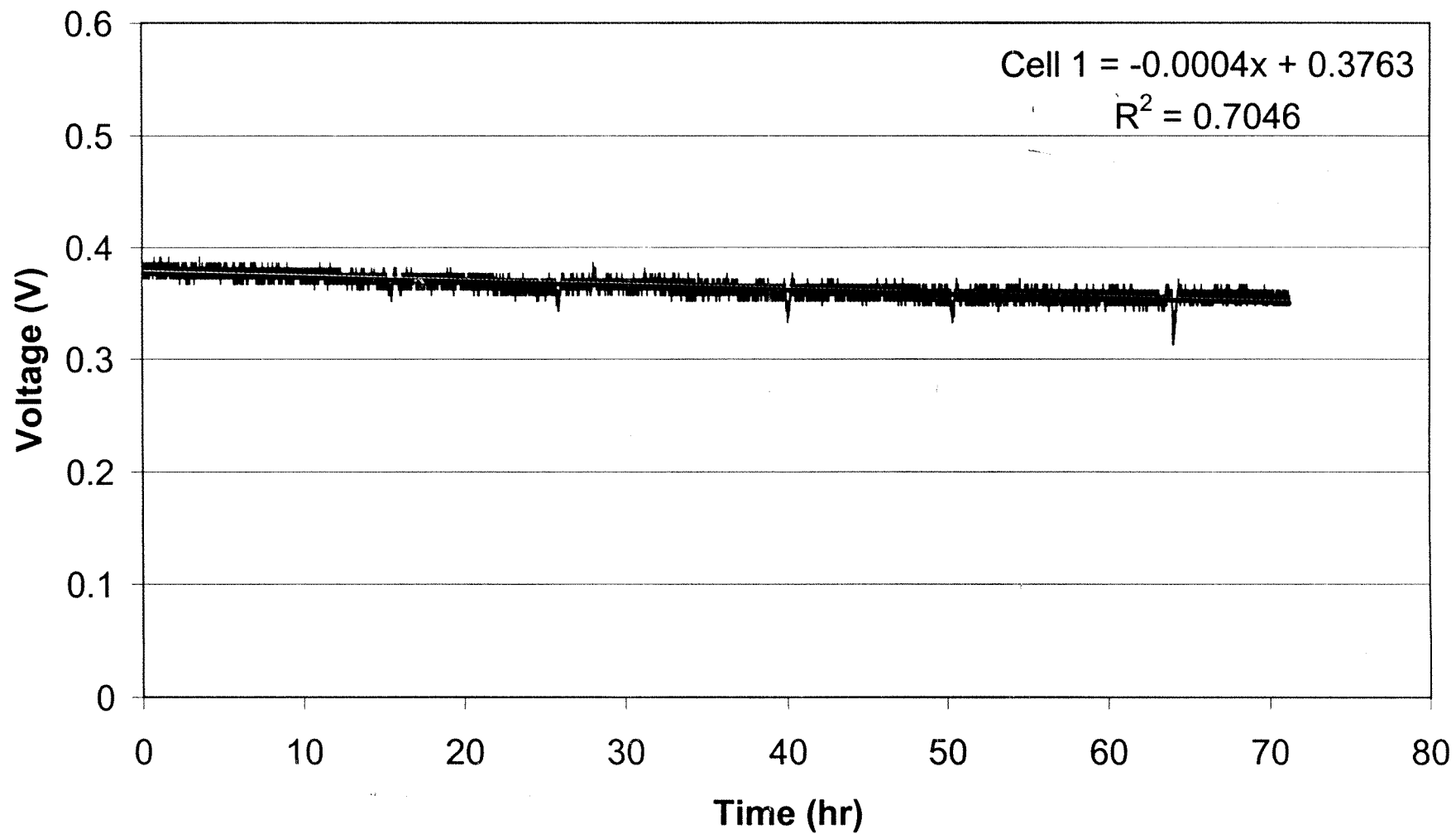
- People
 - Bill Niederhieser, Filiberto Clara, Gordon Hoover, Jake Christiansen, James Gittens and Dr. Andrew Kindler all contributed to the presented data while working at JPL.
- Sponsors
 - The data presented here was a result of DMFC research sponsored by **DARPA**.
 - The work was performed at JPL for Caltech.

Conclusions

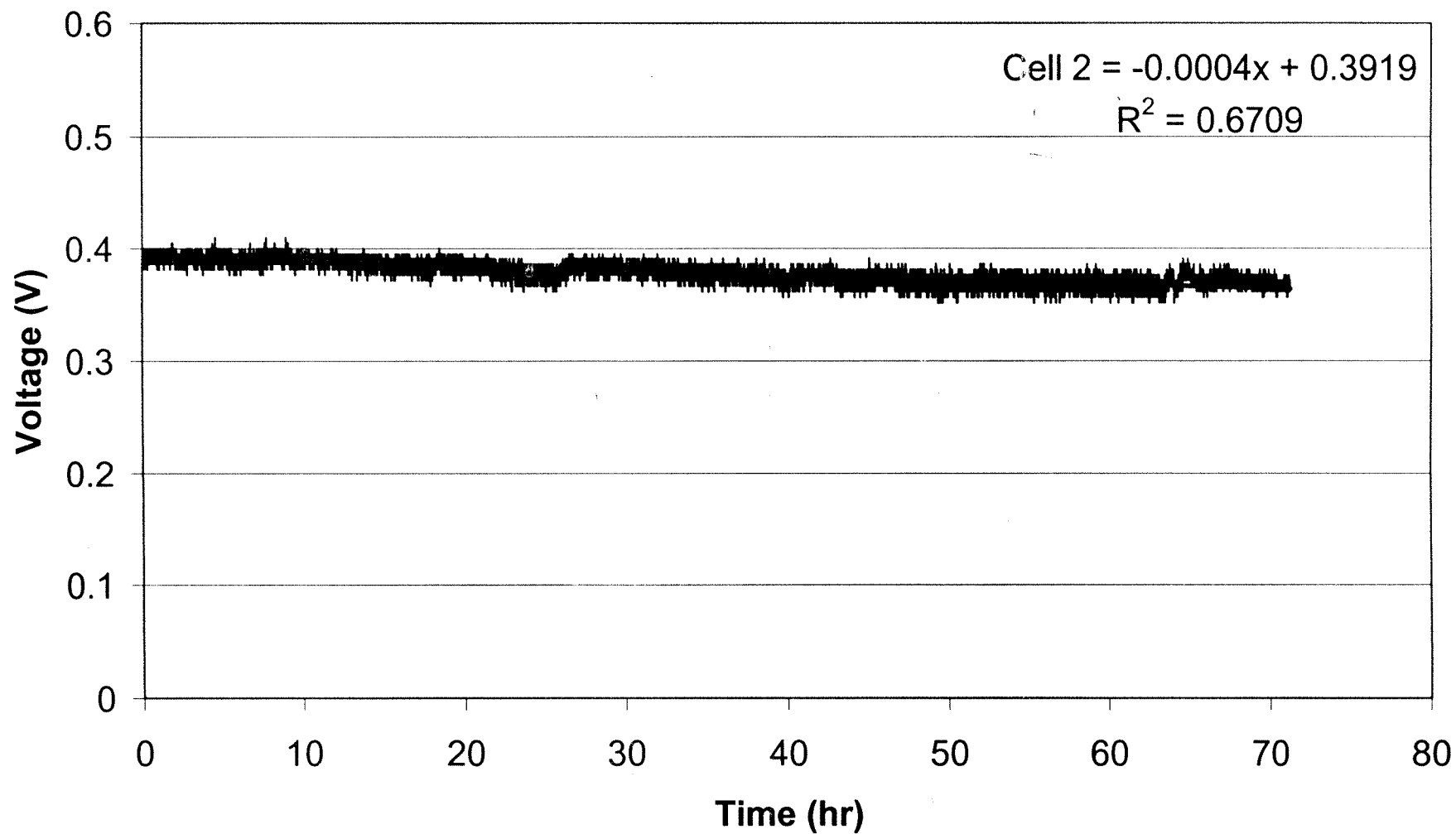
- Temperature and molarity must be accurately controlled for system operation.
 - Methanol Molarity: 0.5M +/- 0.05M.
 - Temperature: 55 °C, +/- 5 °C.
- Maximum airflow is defined by the stack operating temperature.
 - Airflow less than 2 times stoichiometry is required to maintain a system water balance at 55 °C.
- Cathode compartment should be a very open design ~~under~~ for operation of 150-watt system.
 - Decline in stack voltage of 2 mV/hr with current stack configuration.

[B]

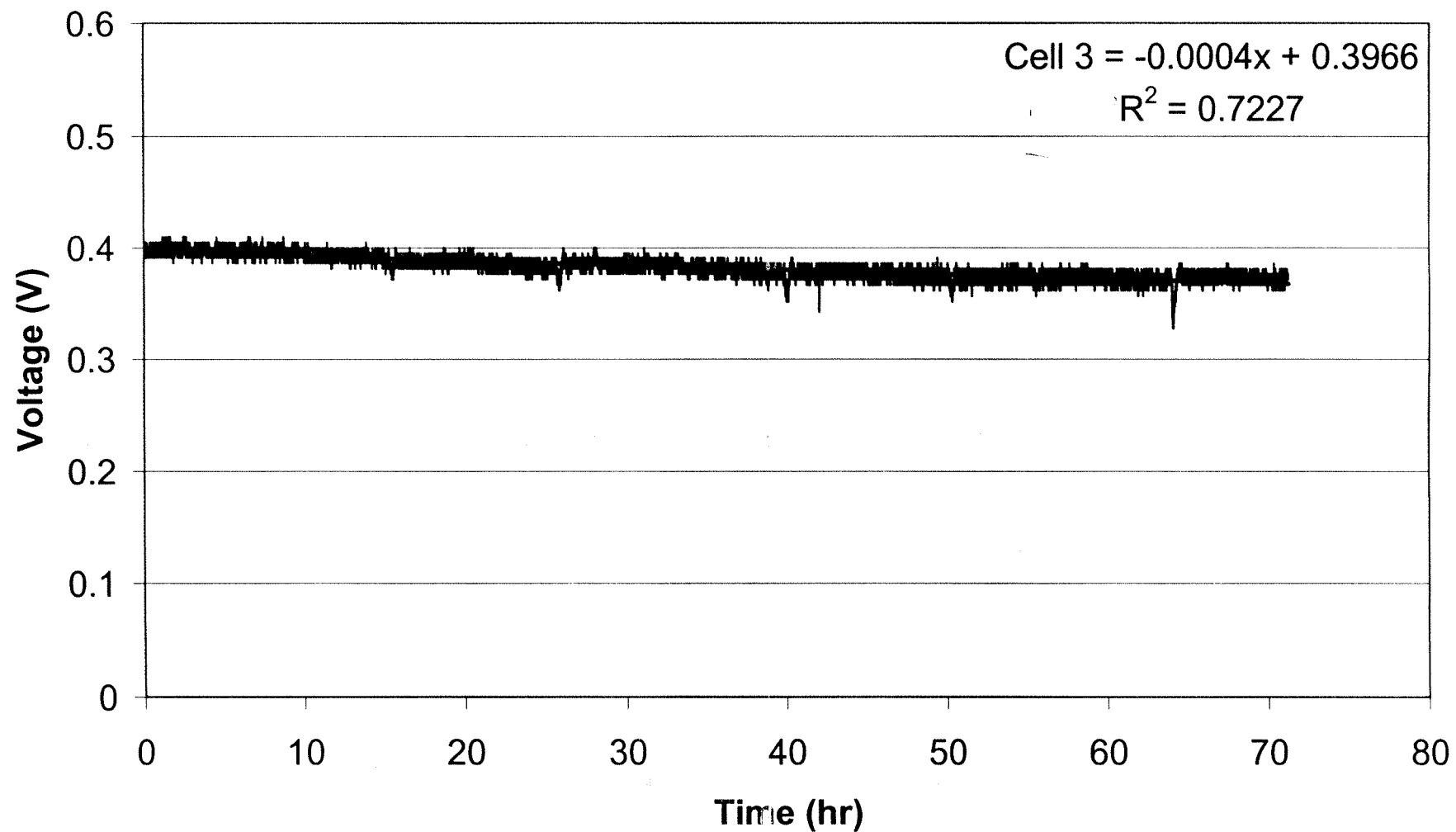
Series Experiment C. Low Flow Stack Life Testing 100mA/cm² Load, 0.5M
MeOH, 200 cc/min MeOH Circulation, 1.75 L/min Air Flow



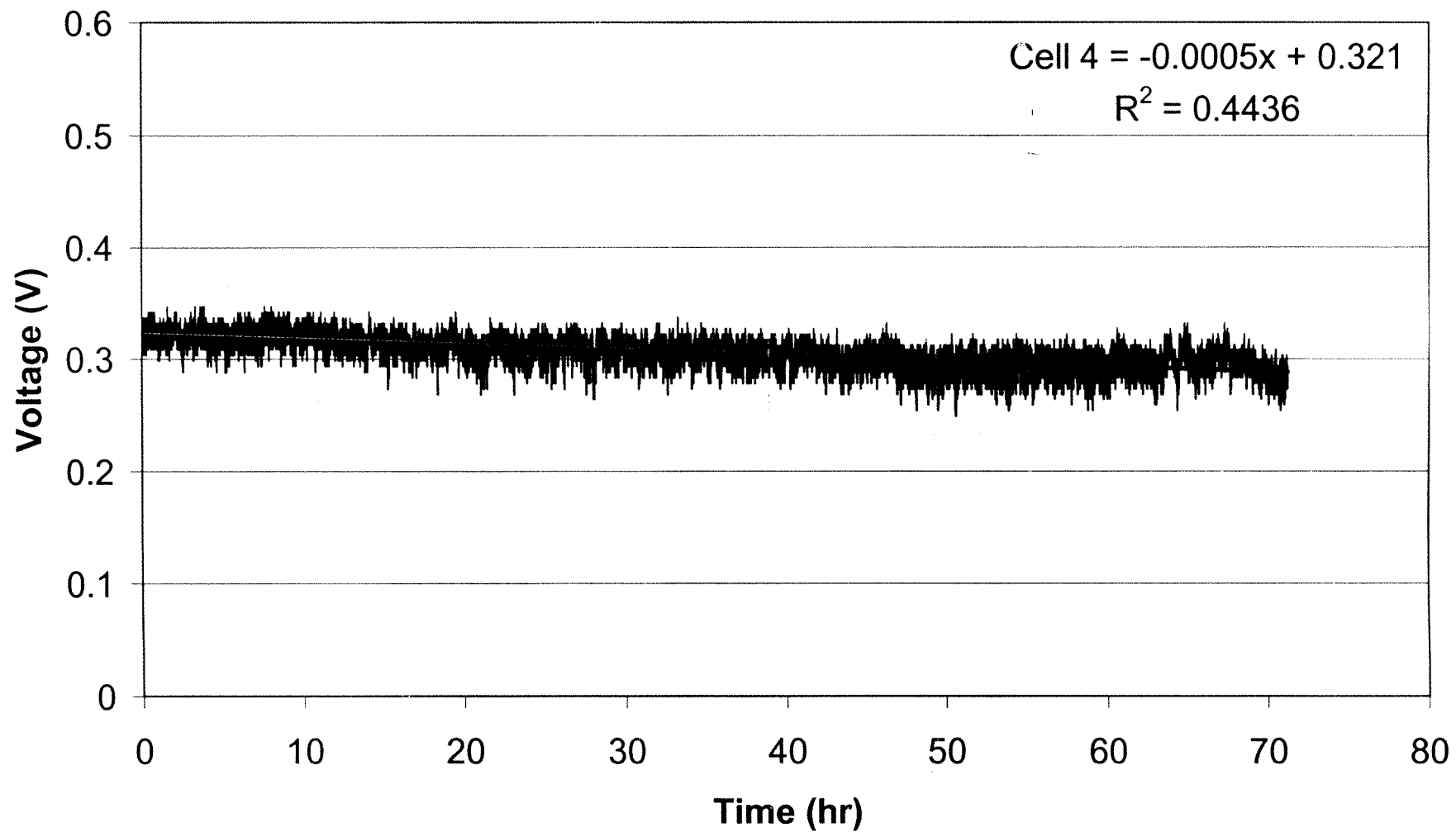
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